Gully Erosion

For planning purposes, all forms of erosion should be considered in determining soil loss for a site. Annual soil loss predictions are made with RUSLE, the WEQ, or both. Erosion that is seasonal and caused by concentrated flow is not predicted by either of these methods. However, seasonal erosion may contribute significantly to the overall erosion on the site. Detailed criteria for distinguishing rills, ephemeral gullies, and gullies are given below. Differentiating among them still may require careful judgment. This is especially true where an ephemeral gully results from runoff that follows tillage marks rather than natural depressions.

A. Definitions

Rills: Rills may be any size, but are usually less than four inches deep. Rills have one or more of the following characteristics:

- parallel on a slope, but may converge
- uniform spacing and dimension
- appear at different locations on the landscape from year to year
- shorter than ephemeral cropland gullies
- end at a concentrated flow channel, terrace, or a where a slope flattens and deposition occurs
- are on the same portion of the slope that is used to determine the length of slope for factor (L) for the RUSLE

Rill erosion is considered in the RUSLE calculations.

Ephemeral Gullies: Ephemeral gullies may be of any size, but are usually larger than rills, with one or more of the following characteristics:

- recur in the same area each time they form rather than random places on the slope
- frequently form in well-defined depressions of natural drainage ways
- tend to occur in the upper reaches of a drainage network
- usually branch, but may have patterns caused by row alignment or other characteristics of field operations
- generally wider, deeper, and longer than the rills on the field
- occur in depressions into which rows or tillage marks lead
- form along sloping rows or tillage marks
- partially or totally erased and filled by tillage operations
- filling results in soil deterioration over a larger area than the gully itself
- occur on terraced fields where overtopping of terraces occurs or piping below the terrace embankment occurs
- occur in the bottom of gradient terraces

Ephemeral gullies are not calculated by the RUSLE.

Gullies: Permanent gullies are channels too deep for normal tillage operations to erase. Special operations are required to fill them. Gullies also have one or more of the following characteristics:

- may grow or enlarge from year to year by head cutting and lateral enlarging
- may also occur in depressions or natural drainage ways
- may begin as ephemeral gully that was left in the field and not erased by tillage or other operations
- may become partially stabilized by grass, weeds, or woody vegetation

Gully erosion is not calculated by the RUSLE.

The soil loss from concentrated flow, gullies, and other similar types of erosion can be determined by calculating the volume of soil removed from the eroded area. The tons of soil loss can then be determined by multiplying the volume removed by the unit weight of soil. If the time period of the erosion exceeds one year, the quantity should be divided by the number of years the gully has existed to get an average annual rate.

B. Gully Erosion Equations

To calculate the erosion occurring from ephemeral gullies or gullies, the following table and formulas will be used:

New gully or channel

$$\frac{(A+B) \times D \times L \times W}{2 \times 2000 \times Y} = T^{1/}$$

Gully bank sloughing

$$\frac{2 \times D \times L \times R \times W}{2000} = T$$

Advancing gully head

$$\frac{(A+B) \times D \times W \times H}{2 \times 2000 \times Y} = T^{1/}$$

Ephemeral gully

$$\frac{(A+B) \times D \times L \times W \times N}{2 \times 2000}$$

A = top width (ft.)
B = bottom width (ft.)
D = depth (ft.)
L = length (ft.)
W = weight (lbs./ft.)

H = headward advancement (ft.)
R = average annual rate of sloughing/recession (ft./yr.)
N = number of occurrences or events per year
T = tons per year
Y = number of years

Examples:

New gully or channel – Eroded silt loam soil; 10 ft top, 2 ft. bottom, 1 ft. deep and 600 ft. long. Formed in 2 years.

$$\frac{(A+B) \times D \times L \times W}{2 \times 2000 \times Y} = T \qquad \frac{(10+2) \times 1 \times 600 \times 85}{2 \times 2000 \times 2} = 76.5 \text{ tons/year}$$

Advancing gully head – Silt loam soil; 6 ft. deep, 30 ft. top, 6 ft. bottom, advancing 5 ft./yr.

$$\frac{(A+B) \times D \times W \times H}{2 \times 2000 \times Y} = T \qquad \frac{(30+6) \times 6 \times 5 \times 85}{2 \times 2000 \times 1} = 23 \text{ tons/year}$$

Gully bank sloughing – Clay loam soil; 2 sides sloughing, 60 ft. long, 4 ft. high, sloughing 1.0 ft/year

$$\frac{2 \times D \times L \times R \times W}{2000} = T \qquad \frac{2 \times 4 \times 60 \times 1.0 \times 85}{2000} = 20.4 \text{ tons/year}$$

Ephemeral gully – Clay loam soil; 3 occurrences (snow melt, tillage, 3" rain, tillage and 6" rain); 4 ft. top, 2 ft. bottom, 0.5 ft. deep and 1,200 ft. long.

$$\frac{(A+B) \times D \times L \times W \times N}{2 \times 2000} \qquad \frac{(4+2) \times 0.5 \times 1{,}200 \times 85 \times 3}{2 \times 2000} = 229.5 \text{ tons/year}$$

The following table provides a guide for approximate unit weight of various soils that can be used in the absence of better data.

APPROXIMATE SOIL WEIGHT 2/	
Soil Textural Class	**Dry Density lb/ft.^{3}**
Sands	110
Loamy sands Sandy loam Fine sandy loam	100
Loams Sandy Clay loams Sandy clay Silt loam Silty clay loam Silty clay Clay loam Clay	85
Ref. Soil Mechanics Module #5	

1/ Data and estimates from published soil surveys, laboratory data, and soil interpretation records are to be used where available. Parent materials, soil consistency, soil structure, pore space, soil texture, and coarse fragments all have an influence on unit weight. (Example - Bulk density on the soil interpretation sheet listed in gm/cm^3 multiplied by 62.4 = lb/ft^3.)

2/ Ephemeral gully erosion may reform several times per year and sometimes does not form during a year. The voided volume which would be calculated after a runoff event would not necessarily be representative of the annual rate but would represent only the specific event. This erosion can be calculated for individual storms and can be summed for a yearly estimate.

This method estimates past erosion and cannot predict future erosion. Tillage in an area affected by ephemeral gullying removes thin layers of topsoil from ungullied areas to fill the gully. The effect on the soil is similar to that from sheet erosion. The total soil loss would include the loss predicted for sheet and rill, wind and the loss from the ephemeral gully area. Annual loss to ephemeral gullying would be determined from the estimated amount voided each year from the ephemeral, divided by the area judged to be affected by the ephemeral gully. Total field erosion is not distributed equally on every acre. When determining management systems for soil erosion reduction all forms of erosion must be accounted for and treated by the most feasible and effective means.

Sheet and Rill Erosion

This section describes methods to estimate soil erosion losses by rainfall and runoff. Sheet and rill erosion is estimated by the use of the Revised Universal Soil Loss Equation (RUSLE) in Kansas. The RUSLE is the management tool used in conservation planning to estimate soil losses by sheet and rill erosion on cropland, pastureland, rangeland, woodland, idle land, and, in some instances, urban areas. The equations quantify the effects of natural factors, cultural management, and cropping practices in soil loss.

The purpose of the RUSLE is to predict long-term average soil losses from specific field areas under specified cropping and management systems. Because of unpredictable short-time fluctuations in the values of influential variables, they are less accurate in predicting specific events than for predicting average soil losses over the entire cropping sequence.

The effectiveness of a particular land treatment alternative can be evaluated when the predicted soil loss for that treatment is compared with the soil loss tolerance "T" for the specific soil.

T = Soil Loss Tolerance. "T" is not part of RUSLE, but is used with RUSLE to establish a benchmark for evaluating the predicted erosion rate from an existing or planned conservation system. "T" is the average annual erosion rate that can occur with little or no long-term degradation of the soil resource on the field. When the computed soil erosion rate is less than the "T" value, control of sheet and rill erosion is assumed to be adequate. When the computed soil erosion rate exceeds the "T" value, sheet and rill erosion is considered to be excessive; and additional conservation treatment is needed. Soil loss tolerance values ("T") are assigned to each soil map unit by the Natural Resources Conservation Service (NRCS).

By using the RUSLE, numerous crop and tillage alternatives can be developed for a particular field or farm. These alternatives can be compared on the basis of predicted soil loss, and they can also be evaluated for effectiveness using "T." This allows the operator to select a system based on the effectiveness to reduce soil loss, feasibility, and economics.

Occasionally, small portions of fields identified during the planning process cannot be completely treated to meet "T" due to topography or physical limitations. In these situations, when water courses or sensitive areas are located down slope, either off-site protection from siltation must be provided or additional land treatment must be utilized to minimize siltation. Some practices such as crop residue management, hay in rotation, and the use of cover crops may compensate for the lack of other treatment.

Even when meeting "T," cropland immediately upslope (above) water courses or sensitive areas may require additional treatment during periods of low residue or crop cover. This is especially true during the part of a crop sequence when crops with high "C" values are utilized.

Additional treatment might include the use and management of crop residues, cover crops, intercropping, or providing a natural or seeded filter strip between the cropland and the water course or other sensitive area.

In summary, RUSLE is an important tool in developing conservation plans which keep soil losses to acceptable levels that will be sustainable over time. This tool is also important in treating surface water quality problems where nonpoint source sediment is an identified problem

Predicting Sheet and Rill Erosion Losses

Revised Universal Soil Loss Equation

RUSLE replaces the Universal Soil Loss Equation (USLE) for predicting soil loss from sheet and rill erosion caused by rainfall and associated overland flow. RUSLE retains the equation structure of USLE. However, each of its factor relationships has been either updated with recent data, or new relationships have been derived based on modern erosion theory and data.

RUSLE is an erosion prediction model that enables conservation planners to predict the long-term average annual rate of sheet and rill soil erosion on a landscape as described by the factor values assigned by the planner. The factors represent the effect of climate, soil, topography, conservation practice, and land use on sheet and rill erosion. Based on assigned factor values for site-specific conditions, RUSLE computes soil erosion rates to guide planning conservation systems for individual fields by evaluating the impact of present and/or planned land use and management.

The soil loss computed by RUSLE is the rate of soil erosion from the landscape profile represented by the particular RUSLE computation--not the amount of sediment leaving a field or watershed. A landscape profile is defined by a slope length. Erosion rate varies along the slope profile, and the erosion rate at the end of the slope length is greater than the average erosion rate for the entire slope length. The calculated soil loss is an average erosion rate for the landscape profile.

The DOS computer version of RUSLE (version 1.05q) was used to develop the values in these erosion prediction tables. To compute the average annual erosion rate on a field slope, select appropriate values from the figures and tables for R, K, LS, C, and P and multiply the values together.

The equation is expressed as follows:

$$A = RKLSCP$$

A = The Predicted Average Annual Soil Loss from Sheet and Rill Erosion from Rainfall and Associated Overland Flow

Units for factor values are usually selected so that "A" is expressed in tons per acre per year.

R = The Factor for Climatic Erosivity

"R" factor values represent the average storm EI value from a 22-year record period

"R" accounts for the amount of rainfall and the peak intensity sustained over an extended period of time and is the number of rainfall erosion index (EI) units in an average year's rainfall.

K = The Factor for Soil Erodibility

"K" values represent the average long term soil and soil profile response to the erosive powers of rainstorm. It represents a large number of erosion and hydrologic processes such as soil detachment, transport by raindrop impact and surface flow, localized deposition, tillage induced roughness, and infiltration. "K" is a measure of the soil loss rate per erosion unit for a specified soil as measured on a unit plot. The unit plot is an erosion plot 72.6 feet long on a uniform 9 percent slope managed in continuous clean till fallow.

L = The Factor for Slope Length

"L" represents the effect of slope length on erosion. "L" is the ratio of soil loss from the field slope length to that from a plot slope 72.6 feet long under otherwise identical conditions. Slope length is the distance from the origin of overland flow along its flow path to the location of either concentrated flow or deposition. Computed soil loss values are not as sensitive to slope length as to slope steepness, thus differences in slope length of + or - 10 percent are not important on most slopes. This is especially true in flatter landscapes.

S = The Factor for Slope Steepness

"S" represents the effect of slope steepness on erosion. "S" is the ratio of soil erosion from the field slope gradient to that from a 9 percent slope under otherwise identical conditions. Computed soil erosion rates are more sensitive to slope steepness than to slope length.

LS = The Slope Length "L" and Steepness "S" Factors That Are Combined Into the "LS" Factor in the RUSLE Equation

An "LS" value represents the relationship of the actual field slope condition to the unit plot. An "LS" value of 1.0 represents the unit plot condition of 72.6 feet in length and 9 percent slope steepness.

C = The Factor for Cover and Management

"C" represents the effect of plants, soil cover, soil biomass, and soil disturbing activities on soil erosion. "C" is the ratio of soil loss from an area with specified cover and management to that from an identical area under tilled continuous fallow management.

P = The Factor for Support Practices

"P" represents the impact of support practices on erosion rates. "P" is the ratio of soil loss from an area with supporting practices in-place to that from an identical area without any supporting practices. Supporting practices include contour farming, cross-slope farming, buffer strips, stripcropping, and terraces.